POSTER SESSION

REDUCTION OF PESTICIDE EXPOSURE BY USING PROTECTIVE CLOTHING AND ENCLOSED CABS

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ABSTRACT

Mixer/loaders, applicators, and maintenance workers may experience high dermal pesticide exposure. For regulatory purposes, protective clothing or engineering controls are well recognized means to reduce dermal exposure to safe levels. Under field conditions, coveralls provide protection depending on type of coverall material, and type and/or formulation of pesticide. In some studies coveralls gave 93% or 96% protection to applicators of phosdrin and dicofol, respectively. Chemical-resistant protective clothing (rainsuit) provided 97% protection to abamectin applicators. Chemical-resistant gloves provided excellent reduction in hand exposure, especially for mixer/loaders. Hand protection can also substantially reduce harvester exposure. Enclosed cabs (positive pressure/air-filtering systems) can provide up to 98% reduction in airborne residues. During the risk management phase of the risk assessment process, modifications of protective clothing strategies may be needed to increase margins of safety for short-term effects or reduce excess cancer risk. Protection provided by protective clothing and engineering controls is summarized and reviewed.

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INTRODUCTION

Many pesticides have low acute toxicity but have been shown to cause other adverse effects in experimental animals. Some of the adverse effects of concern are carcinogenicity, mutagenicity, and reproductive/developmental toxicity. Excessive exposure of workers, particularly pesticide handlers (including mixers, loaders, and applicators), maintenance workers, and harvesters to these pesticides must be mitigated to a safe level. It is well established that the majority of total pesticide exposure is by dermal contact for all but the most volatile chemicals. The reduction of dermal exposure can be effectively accomplished by using engineering controls and protective clothing.

There are various types of protective clothing available for reducing pesticide exposure. Different fabrics, woven and non-woven, are used to make this clothing. Some laboratory testing results are available, but they have limited value when extrapolated to protection under field use conditions. Lab test results such as permeation, tensile strength, absorbency, air permeability, or wicking are useful indicators of fabric quality and idealized protection. However, field test data for pesticide protection utilizing protective clothing are limited. Results obtained under field conditions are more representative, because there are many factors that may influence clothing penetration of pesticides. Besides the quality of fabric material, the factors that are likely to affect the evaluation of clothing penetration are: degree of pesticide contamination during work, contamination from vapor, openings in clothing, seams, the "bellows" effect, weave flexure and work habbits.

Some other factors should also be considered in selecting protective clothing besides the effectiveness in pesticide protection. Thermal comfort, availability, cost and acceptability by the workers are some of these considerations. This paper presents surveys of protection provided by protective clothing and engineering controls conducted under field conditions.

METHODS

Data presented are from field trials conducted by the Worker Health and Safety Branch, California Department of Food and Agriculture and from published reports. Percent penetration or protection provided by protective clothing and engineering controls were determined as follows:

A. Clothing penetration

Dosimetry patches were placed outside and underneath clothing in the same proximity (not occlusive). Multilayer patches or cotton underwear may be used to estimate potential dermal exposure and dermal exposure. (Percent clothing protection is 100 - percent clothing penetration.)

$$\% \text{ penetration} = \frac{\text{Residues of inside patches}}{\text{Residues of outside patches}} \times 100$$

$$\% \text{ penetration} = \frac{\text{Dermal exposure}}{\text{Potential dermal exposure}} \times 100$$

B. Enclosed cab protection

$$\% \text{ Protection} = 100 - \frac{\text{Air conc. inside enclosed cab}}{\text{Air conc. outside enclosed cab}} \times 100$$

$$\% \text{ Protection} = 100 - \frac{\text{Potential dermal exp. inside cab}}{\text{Potential dermal exp. outside cab}} \times 100$$

SURVEY OF AVAILABLE PROTECTIVE MATERIALS

EXAMPLES OF FABRICS AND COATING MATERIALS FOUND IN WORK CLOTHING AND PROTECTIVE CLOTHING

A. Woven fabrics

1) Work clothing (Long-sleeved shirt, long pants)

100 % cotton chambray (woven-plain)
100 % cotton denim (woven-twill)
50/50 cotton/polyester twill
65/35 polyester/cotton (woven-twill)

2) Work clothing (Coveralls or overalls)

Tyvek (uncoated)
65/35 polyester/cotton
Polypropylene (uncoated)
100 % cotton
100 % polyester (spun dacron)
100 % nylon (spun nylon)
100 % acrylic (spun orlon)

B. Non-woven and composite fabrics

Tyvek (spun-bonded olefin) coated with polyethylene
Tyvek laminated with Saranex
Polypropylene laminated with polyethylene
Gore-tex (Composite cotton/PE woven face & a polyester Jersey-knit back.
Polyvinylchloride

C. Water repellent finish or coating and impervious materials

Fluorocarbon aliphatic resin (eg. Scotchgard)
Polyethylene
Saranex(85% vinylidene chloride/15% vinyl chloride copolymer)
Polyvinylchloride
Polytetrafluoroethylene
Durable press finish

PERCENT CLOTHING PENETRATION FROM FIELD STUDIES FOR DIFFERENT PESTICIDES

Composition	Pesticide	% Clothing penetration
A. Work clothing[a]		
ND	Carbaryl (4 studies)	7
ND	Dicofol	9
ND	Malathion	16
ND	Ethion	28
ND	Cycloate	38
ND	EPTC	47
B. Work clothing[b]		
Cotton/polyester	Oxydemeton-methyl	0
Cotton/polyester	Ethion	4
Cotton/polyester[c]	Ethion	4
Cotton/polyester	Toxaphene	3
Cotton/polyester	Captafol	5
Cotton/polyester	Triadimefon	7
Cotton/polyester	Phosdrin	7
Cotton/polyester	Propargite	9
Cotton/polyester	Propargite	15
Cotton/polyester	Isofenphos	16
Cotton/polyester	Dichlorvos	20
Cotton/polyester	Abamectin[d]	15
Cotton/polyester	Carbaryl	11
Tyvek	Fluvalinate	1
Tyvek	Dicofol	4
Tyvek	Paraquat	4
Tyvek	Chlorpyrifos	11
Tyvek	Ethazol	34
C. Chemical resistant		
Rainsuit (PVC)	Abamectin	3
Rainsuit (PVC)	Dinocap	5
Rainsuit (PVC)	Dinocap, mancozeb	0
Gore-Tex	Dinocap, mancozeb	0
Gore-Tex[e]	Nitrofen	0
D. Chemical resistant apron		
ND	Chlorothalonil	1
ND	Chlorpyrifos	11
ND	Fluvalinate	22
ND	Ethazol	52

a Long-sleeved shirt, long pants.
ND Not determined.
b Coveralls or overalls.
c Treated.
d Contaminated.
e Teflon coated.

REDUCTION OF PESTICIDE EXPOSURE BY USING ENGINEERING CONTROLS

A. Protection by enclosed cab[a] determined from airborne residues

Pesticides	Pesticide concentration (ug/m^3) Outside cab	Inside cab	% Protection
Chlorpyrifos, site 1[b]	47.0	0.6[c]	98.7
Chlorpyrifos, site 2[b]	45.0	1.6[c]	96.4
Chlorpyrifos, site 3[b]	77.0	1.1[c]	98.6
Parathion, site 5[b]	4.5	0.3[c]	93.3
Parathion, site 7[b]	27.0	0.3	98.9
Parathion	1310.0	0.0	100.0
Parathion[b]	11.2	0.6	95.0
Propargite, site 7[b]	33.0	0.1[c]	99.7
Phosalone, site 8[b]	32.0	0.03[c]	99.9
Demeton	240.0	0.0	100.0
Oxydemeton-methyl	28.2[d]	0.11[d]	99.6
		Mean	98.2±2.3

a With positive air pressure and a charcoal air-filtration unit.
b Study sites in California
c Based on MDL
d ug/L

Pesticides	Eight hour TWA (ug/m^3) Outside cab	Inside cab	% Protection
Demeton[e]	0.39	0.27	31
Diazinon[e]	1.67	0.18	89
Dimethoate[e]	0.64	0.21	67
Methamidophos[e]	2.00	1.06	47

e Air-conditioned enclosed cab tractor, no carbon filtration. (Results were from one experiment.)

B. Protection by enclosed cab determined from patch residues

Pesticides	% Protection
Paraquat[f] (air-conditioned enclosed cab, tractor)	84
Paraquat[f] (air-conditioned high clearance, tractor)	89
Parathion[g] (enclosed cab, tractor)	99.7
Dimethoate[g] (enclosed cab, tractor)	99.1

f Applicators wore long- or short-sleeved shirts, long pants, socks, heavy shoes or boots. Ground boom application equipment was used.
g Airblast spray equipment was used.

EXAMPLES OF APPROVED COVERALLS AND RAINSUITS FOR PESTICIDE PROTECTION

A. Coveralls made of the following fabrics meet the basic coverall work clothing requirement of Section 6736 of California Code of Regulations (CCR):

KleenGard
Polypropylene (uncoated)
Tyvek Q (uncoated)

B. Coveralls made of the following fabrics meet the more stringent chemical resistant requirements of Section 6738(d) of the CCR:

Encase II
Polypropylene laminated with polyethylene
Tyvek QC (laminated with polyethylene)
Tyvek laminated with Saranex

The above mentioned protective clothing is provided as an example of appropriate types of clothing. Other clothing providing a similar standard of protection is also acceptable.

DEFAULT VALUES FOR PESTICIDE PROTECTION PROVIDED BY CLOTHING AND ENGINEERING CONTROLS

Worker Health and Safety Branch, California Department of Food and Agriculture, generally uses the following default percent protection for protective clothing and protection provided by engineering controls in promulgating exposure mitigation measures. Evaluation of these numbers is an ongoing research activity. Physical and chemical properties and pattern of use may lead to the utilization of modified values.

	% Protection
A. Work clothing and protective clothing	
Normal work clothing worn by worker*	90
Coveralls or overalls	90
Chemical resistant full body protective clothing (rainsuits)**	95
Chemical-resistant gloves	90
B. Engineering controls	
Closed mixing and loading system plus chemical resistant apron and gloves	95
Enclosed cab with positive pressure and a charcoal air-filtration unit	98
C. Respiratory protection	
Enclosed cab with positive pressure and a charcoal air-filtration unit	98
Half face respirator with cartridges (Approved by NIOSH and/or MSHA)	90
Full face respirator with cartridges (Approved by NIOSH and/or MSHA)	98

* Such as long-sleeved shirt and long pants.

** Under CCR, the following conditions apply when full body chemical resistant protective clothing are used: If working environment can not be maintained at 80 ^{o}F during daylight hours or 85 ^{o}F during nighttime hours (sunset to sunrise), cooled chemical resistant suits must be used.

These default protective values may be used only when there are no appropriate data or when data are not available for a specific pesticide. Highly volatile pesticides will likely reduce the effectiveness of protective clothing or engineering controls. Protection by clothing and engineering controls from such pesticides will be taken into special consideration.

CONCLUSIONS

1. Chemical resistant protective clothing provided excellent protection for dermal pesticide exposure under field conditions. Mean percent protection was 98.9±2.0 (n=7).

2. Coveralls or overalls also gave effective protection. Percent protection ranged from 80 to 100 (excluding high penetrating ethazol). Mean protection was 92±5.8 percent (n=17).

3. Pants and shirt (work clothing) made of different fabrics provided average protection of 88.4±8.0% (n=7) (excluding highly penetrant cycloate and EPTC).

4. Protection provided by chemical resistant apron ranged from 78 to 99 percent (n=3) (excluding highly penetrant ethazol).

5. Enclosed cabs with positive pressure and a charcoal air filtration unit provided excellent protection (98.2±2.3 percent; n=11) from airborne residues and dermal exposure. This is far superior to protection provided by an enclosed cab without air filtration (58.5±25.1 percent protection; n=4).

6. From this survey, protection provided by different protective clothing regimens and engineering controls is similar to the default values. Revision of these default values will be made accordingly as adequate data obtained from ongoing surveys and research activities warrant changes.

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1. Percent Clothing Penetration from Field Studies for Different Pesticides

Composition	Pesticides	% Clothing penetration	References
A. Work clothing[a]			
ND	Carbaryl (4 studies)	7	Gold *et al.*, 1982; Leavitt *et al.*, 1982; Lillie *et al.*, 1981; Raheel, 1988.
ND	Dicofol	9	Nigg *et al.*, 1986.
ND	Malathion	16	Fenske *et al.*, 1986.
ND	Ethion	28	Davies *et al.*, 1982.
ND	Cycloate	38	Dong, 1991.
ND	EPTC	47	Knaar and Iwata, 1986
B. Work clothing[b]			
Cotton/polyester	Oxydemeton-methyl	0	Fong *et al.*, 1990.
Cotton/polyester	Ethion	4	Davies *et al.*, 1982
Cotton/polyester[c]	Ethion	4	Davies *et al.*, 1982
Cotton/polyester	Toxaphene	3	Wang *et al.*, 1983.
Cotton/polyester	Captafol	5	Popendorf, 1988.
Cotton/polyester	Triadimefon	7	Mehler and Formoli, 1991.
Cotton/polyester	Phosdrin	7	Maddy *et al., 1981.*
Cotton/polyester	Propargite	9	Thongsinthusak, *et al.*, 1989.
Cotton/polyester	Propargite	15	Thongsinthusak *et al.*, 1989.
Cotton/polyester	Isofenphos	16	Brodberg, 1990.
Cotton/polyester	Dichlorvos	20	Gold and Holcslaw, 1985.
Cotton/polyester	Abamectin[d]	15	Rech *et al.*, 1988.
Cotton/polyester	Carbaryl	11	Leavitt *et al.*, 1982.
Tyvek	Fluvalinate	1	Stamper *et al.*, 1989.
Tyvek	Chlorothalonill	4	Stamper *et al.*, 1989.
Tyvek	Paraquat	4	Formoli and Ross, 1991.
Tyvek	Chlorpyrifos	11	Stamper *et al.*, 1989.
Tyvek	Ethazol	34	Stamper *et al.*, 1989.

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C. Chemical-resistant

Rain suit (PVC)	Abamectin	3	Rech *et al.*, 1988.
Rain suit (PVC)	Dinocap	5	Fong and Krieger, 1988.
Rain suit (PVC)	Dinocap, mancozeb	0	Norton *et al.*, 1988.
Gore-Tex	Dinocap, mancozeb	0	Norton *et al.*, 1988.
Gore-Tex[e]	Nitrofen	0	Putman *et al.*, 1983.

D. Chemical-resistant apron

ND	Chlorothalonil	1	Stamper *et al.*, 1989.
ND	Chlorpyrifos	11	Stamper *et al.*, 1989.
ND	Fluvalinate	22	Stamper *et al.*, 1989.
ND	Ethazol	52	Stamper *et al.*, 1989.

[a] Long-sleeved shirt, long pants [b] Coveralls or overalls [c] Treated
[d] Contaminated [e] Teflon coated ND: Not determined

2. Reduction of Pesticide Exposure by Using Engineering Control

A. Protection by enclosed cab determined from airborne residues (positive air pressure and a charcoal air-filtration unit)

A.1 Based on pesticide concentration (ug/m^3)

Pesticides	% Protection	References
Chlorpyrifos, site 1	98.7	Gibbons, 1990.
Chlorpyrifos, site 2	96.4	Gibbons, 1990.
Chlorpyrifos, site 3	98.6	Gibbons, 1990.
Parathion, site 5	93.3	Gibbons, 1990.
Parathion, site 7	98.9	Gibbons, 1990.
Parathion	100	Taschenberg *et al.*, 1975.
Parathion	95	Wang *et al.*, 1987.
Propargite, site 7	99.7	Gibbons, 1990.
Phosalone, site 8	99.9	Gibbons, 1990.
Demeton	100	Taschenberg *et al.*, 1975.
Oxydemeton-methyl	99.6	Taschenberg *et al.*, 1975.

A.2 Based on 8-hour TWA (ug/cm^3) (air-conditioned enclosed cab tractor, no carbon filtration).

Demeton	31	Maddy and Richmond, 1987.
Diazinon	89	Maddy and Richmond, 1987.
Dimethoate	67	Maddy and Richmond, 1987.
Methamidophos	47	Maddy and Richmond, 1987

B. Protection by enclosed cab determined from patch residues.

Pesticides	% Protection	References
Paraquat (air-conditioned, enclosed cab, tractor)	84.0	Woject *et al.*, 1983.
Paraquat (air-conditioned high clearance, tractor)	89.0	Woject *et al.*, 1983.
Parathion (enclosed cab, tractor)	99.7	Carman *et al.*, 1982.
Dimethoate (windows closed, truck)	99.1	Carman *et al.*, 1982

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